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# TIME DELAY MEASUREMENTS IN THE FREQUENCY DOMAIN FOR INDOOR RADIO PROPAGATION

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## ABSTRACT

Measurement results of average time delay and RMS delay spread are reported. A statistic of RMS delay spread is presented. A linear regression analysis between the above delay times and the T-R separation is also described. Using a method to discard the location with the maximum absolute error, this regression analysis allows us to obtain a minimum mean square error (MMSE) line with more important correlation coefficient and more reduced mean square error.

## INTRODUCTION

Indoor radio propagation has been studied extensively for the evaluation of different transmission systems for application in portable phones and wireless local area networks. The reported measurements for indoor radio channel have been performed almost exclusively in the time domain [1-4]. Recently, similar measurements were performed in the frequency domain [5-6] using a network analyzer.

The measurements described in this paper were performed with a simplified version of the setup initially used by Pahlavan and Howard [6] and improved by Zagioul *et al.* [7]. It represents the first report of time delay and RMS delay spread results of an indoor radio channel measurement campaign conducted at LCST laboratory in the Summer of 1991.

## DESCRIPTION OF THE MEASUREMENTS

The block diagram of the measurement setup used for frequency domain characterisation of the indoor radio channel is shown in Fig.1. A more detailed description of the measurement setup is given in Reference [8].

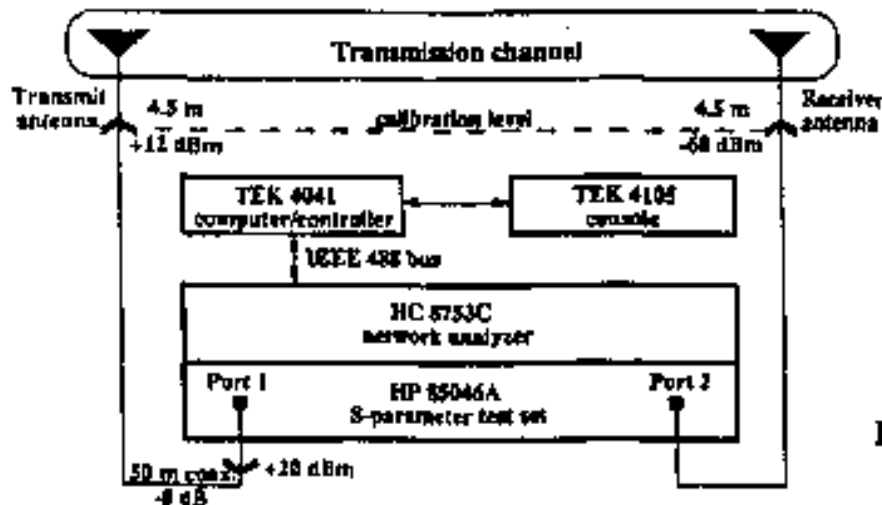


Fig. 1

The frequency response of the channel consists of 801 complex samples at a frequency spacing of 0.25 MHz for a frequency span of 200 MHz, which is centered at 0.9 MHz. From this frequency response, a time response of 4000 ns duration is derived. The time response is truncated to keep only that portion with significant energy.

## MEASUREMENT ANALYSIS

The data rate limitations for digital transmission systems is limited by the frequency selective fading multipath characteristics of the channel. In the time-domain measurements, the data rate limitations are studied by examining the statistics of the RMS delay spread [1-4]. For the frequency-domain measurements, the same analysis may be realized using the time-response  $h(t,x)$  derived from the frequency-response  $H(f,x)$  as explained above. The RMS delay spread  $\tau_{rms}$  is computed by [1,6]:

$$\tau_{rms} = \sqrt{\bar{t}^2 - \bar{t}^2} \quad (1)$$

where [6]:

$$\bar{t}^i = \frac{\int_0^{\infty} t^i |h(t,x)|^2 dt}{\int_0^{\infty} |h(t,x)|^2 dt} \quad , i = 1,2 \quad (2)$$

For each location  $x$ , a value for  $\bar{t}$  and  $\tau_{rms}$  were obtained. Fig.2. shows the cumulative distribution function (CDF) of RMS delay spread values. The CDF shows the probability that  $\tau_{rms}$  is greater than the value given on abscissa. The result is similar to the others, all ready communicated [3,4].

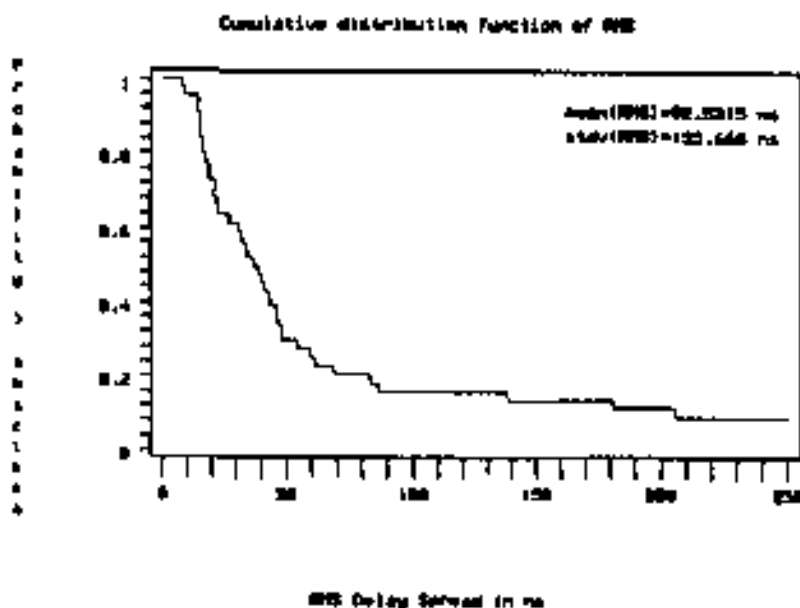


Fig.2.

Fig.3. is a scatter plot of the  $\bar{t}$  and  $\tau_{rms}$  as functions of the distance between the transmitting and receiving antennas. The linear regression lines shows that the both time parameters generally increase with T - R separation. The correlation coefficient are quite low (0.7 for  $\bar{t}$ , 0.52 for  $\tau_{rms}$ ) and the error is quite important ( $\epsilon = 61.5$  ns for  $\bar{t}$  and  $\epsilon = 115.3$  ns for  $\tau_{rms}$ ). The both graphics indicate the existance of a location with a very important error: the anechoic chamber. For this location there was no LOS between the antennas. This observation suggests to modify the analysis, in order to discard this location. In fact, the analysis program was improved, in order to identify the location with the most important error, to discard this location and to repeat the regressive analysis. The results are shown in Table 1 and Table 2.

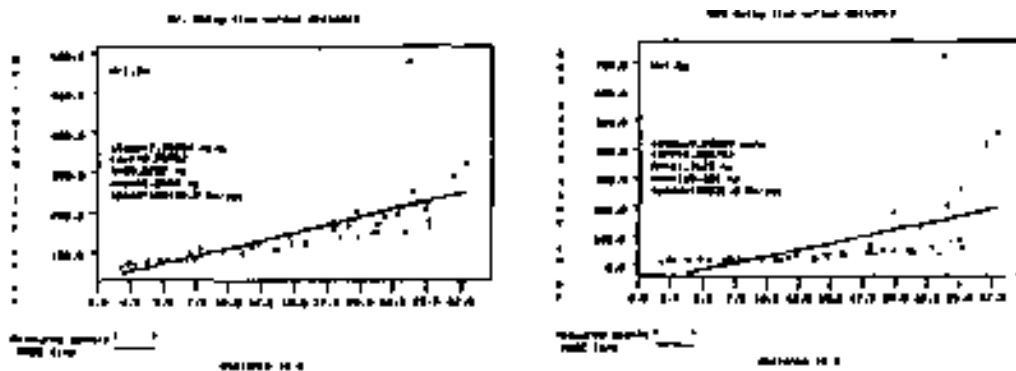


Fig.3.

Table 1 Parameters for average delay time

Data	$\bar{t}$				
	corr	error (ns)	slope (ns/m)	intercept (ns)	speed ( $\times 10^3$ Km/s)
all data	0.707	61.56	7.99	29.87	125
31	0.891	26.71	6.83	39.35	146
31,34	0.904	22.59	6.34	44.55	157
31,34,32	0.917	19.02	5.92	48.82	168
31,34,32,30	0.930	16.45	5.66	51.13	176
31,34,32,30,28	0.936	15.51	5.57	51.52	179

Table 2 Parameters for RMS delay spread

Data	$\tau_{rms}$			
	corr	error (ns)	slope (ns/m)	intercept (ns)
all data	0.526	115.3	9.25	-61.76
31	0.597	77.03	7.45	-47.00
31,34	0.582	62.27	5.90	-30.60
31,34,32	0.608	42.29	4.37	-14.87
31,34,32,33	0.620	33.07	3.57	-7.32
31,34,32,33,30	0.639	26.01	2.97	-2.10

Using the results presented above, some conclusions can be pointed out:

1) the elimination of the location placed in the anechoic chamber increases the correlation coefficients and significantly decreases the errors between measured points and MMSE line;

2) the correlation coefficient generally increases with decreasing error;

3) the successive elimination of the locations with the greatest errors coincide with increasing values for the average propagation speed. So, this locations have the longest paths between antennas. It is significant that the locations are nearly the same for the both parameters. Using the plan of the groundfloor of the LCST laboratory (the test area), it may be seen that all this locations are placed in a corner of the "Hyperfréquences" chamber, next to the anechoic chamber;

4) for RMS delay spread, even after the elimination of several locations, the correlation coefficient rests quite small. So, the RMS delay time is weakly correlated with T - R separation. It depends on the concrete architecture of the building.

### **CONCLUSION**

We presented the results of 0.8 - 1 GHz multipath propagation measurements performed in the frequency domain using a network analyzer. For each location, the frequency response of the indoor radio channel was measured and the time-response was computed. Then, the average time delay and RMS delay spread was 250 - 300 ns. The measured RMS delay spread has a mean of 82.5 ns and a standard deviation of 135 ns. This large values are due to the anechoic chamber. It may be shown that the elimination of some locations decreases the RMS delay spread range at 10 - 70 ns, with lower mean and standard deviation.

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